Modeling the Stellar Jitter for the Reduction of Stellar Radial Velocity Noise for Star HD121504

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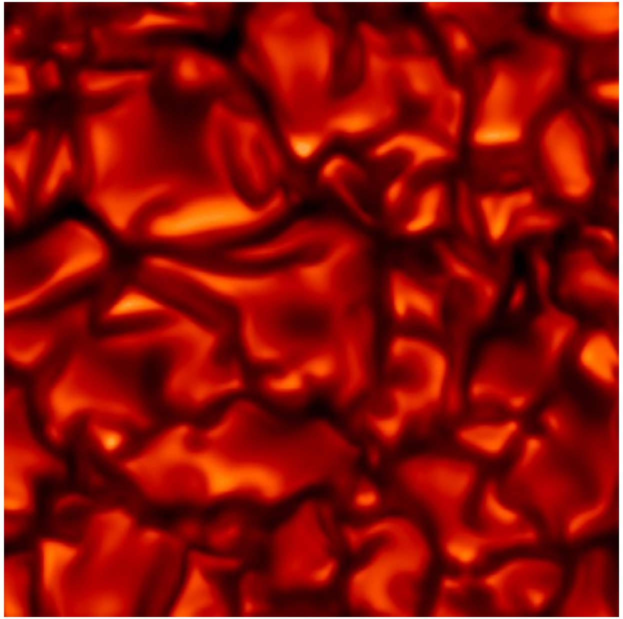
Role of Stellar Jitter in Stellar Radial Velocity Measurements

- Currently, the detection of Earth-Mass exoplanets via the radial velocity (RV) method is difficult due to significant contamination of RV signal from disturbances originating from turbulent photospheric dynamics
- This RV noise is referred to as the ‘Stellar Jitter’
- While the RV disturbance of a Sun-mass star orbited by an Earth-mass exoplanet is of the order of 0.1 - 1 m/s, the RV signal accociated with the stellar jitter is typically of the order of 100 m/s



The Stellar Jitter Project

The Stellar Jitter project aims to address the issue of stellar jitter affecting the RV measurements of stars which may harbor Earth-mass exoplanets.

Using SPINOR code from a pre-computed 3D radiative model of the stellar atmosphere, we generate a series of synthetic spectral observations of the star HD121504 for many iron I (Fe-I) absorption lines to investigate the surface dynamics of this star.

HD121504:

- Sun mass star ($M=1.18\ M_{\odot}$)
- Known host of Jupiter size planet ($m=1.22\ m_J$)
- Spectral Type G2V

Methodology

StellarBox Code → **Spinor Code** → **Synthetic data** → **Post Processing Scripts** → **Disk Integration**

StellarBox Code

3D radiative model of upper stellar convection zone and lower atmosphere

Spinor Code

Computation of synthetic data for individual Fe-I lines profiles (±0.35Å) at various locations on the stellar disk (12.8Mm x 12.8Mm)

Synthetic data

29 Fe-I Lines (Visual):

Locations:

Every 15° in radial angle (0° - 75°) & every 30° in polar angle

Timeseries:

18.0 hours, Δt=60s

Post Processing Scripts

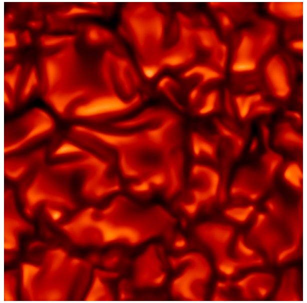
Computation of data for each snapshot-integrated absorption line profile:

- Doppler Shift
- Continuum Intensity
- FWHM
- Bisector

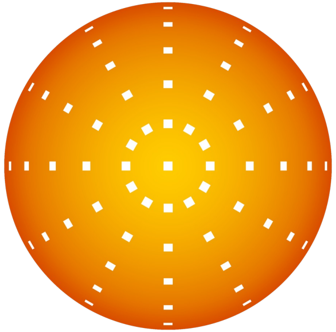
Disk Integration

Weighted integration of synthetic data over entire stellar disk

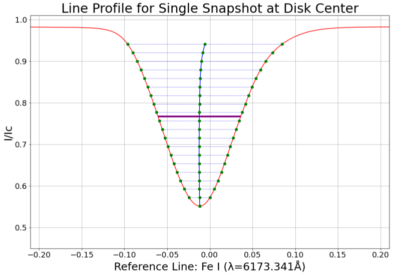
- Calibrate depth using real observations
- Observe changes in doppler shift over time



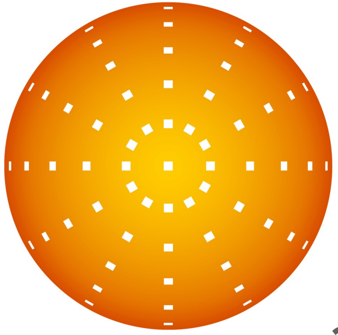
Synthetic “Raw” Data



Disk Locations



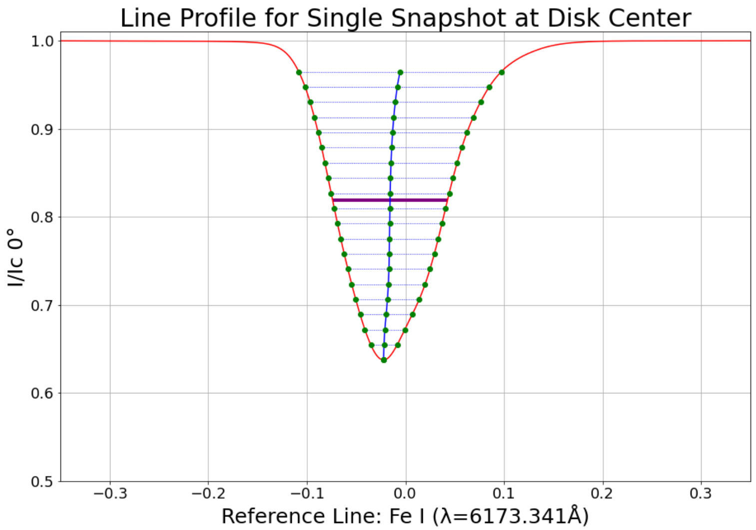
Snapshot-Integrated Spectrum

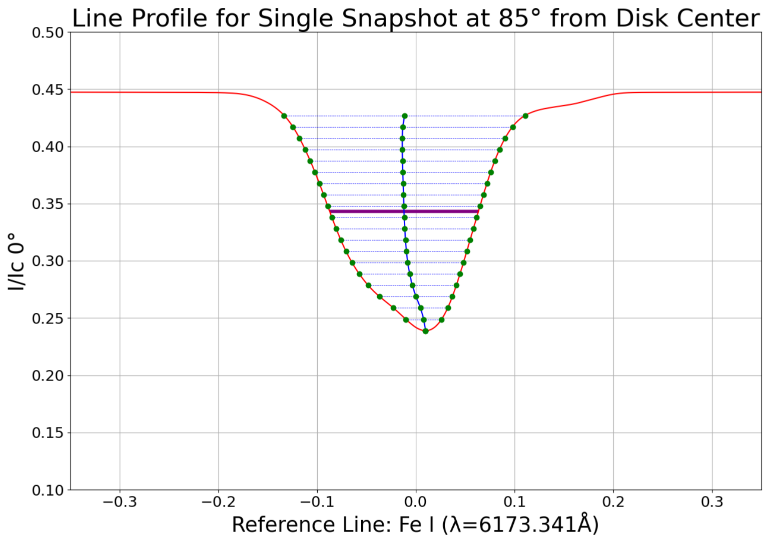


Disk Integration

Synthetic Line Profiles

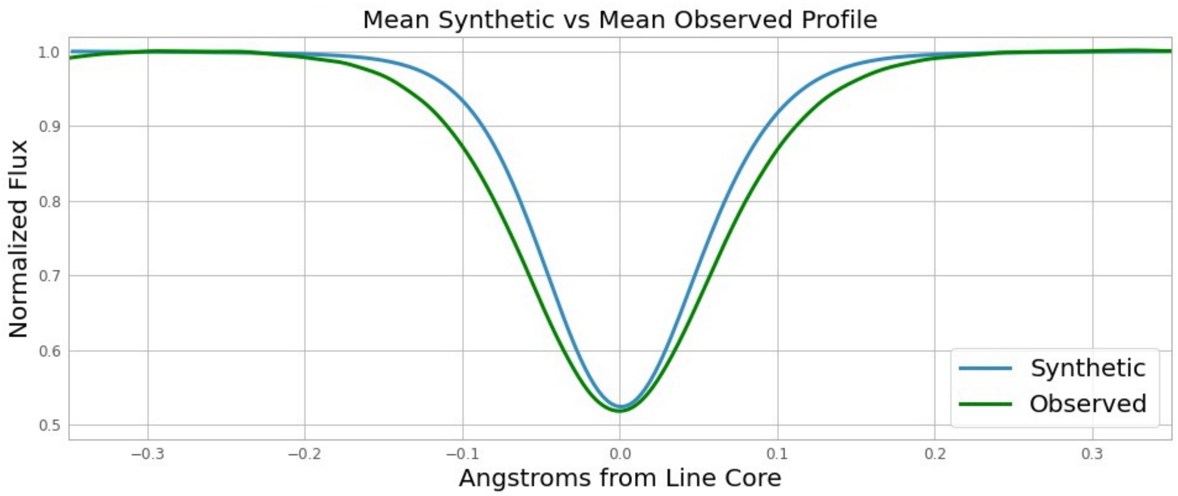
- Profiles closer to stellar limb exabit effects of limb darkening
- Profiles near disk center tend to be slightly blue-shifted and more narrow
- Profiles near limb tend to be irregular in shape and do not exhibit as much preference towards blue or red shift when compared to disk center





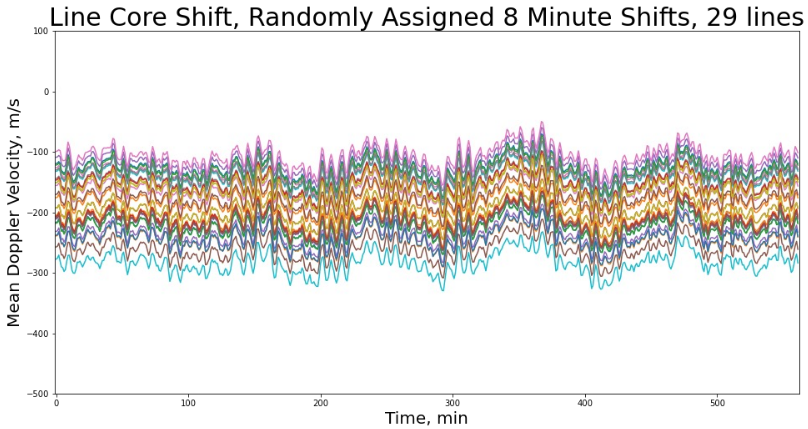
Disk-Integrated Line Profiles vs Observed Profiles

- Integrated profiles are compared to observations of HD121504 by the ESO HARPS Instrument for depth calibration
- Currently, the synthetic profiles are consistently narrower compared to the observed profiles
    - Potentially due to insufficient sampling near limb



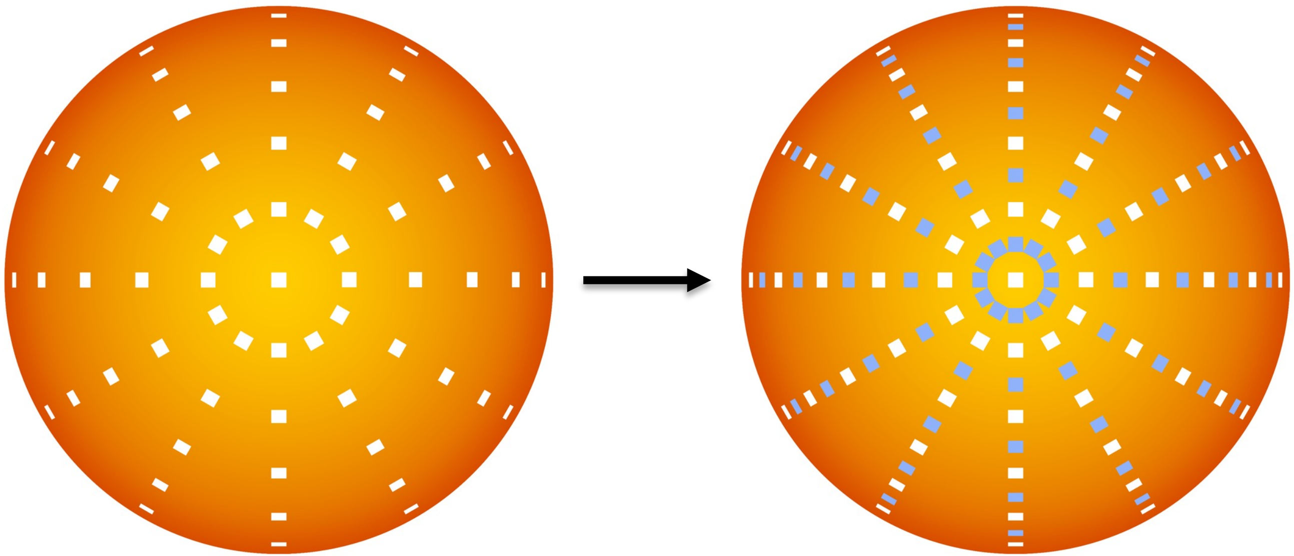
Disk-Integrated Doppler Velocities

- To prevent resonance effects originating from identical dynamics at every point on the disk, each location is randomly shifted in time
- Each location should have a Δt of at least 8 minutes from all other locations (lower length of granule life (e.g., Bahng, J., & Schwarzschild, 1961))



Interpolation

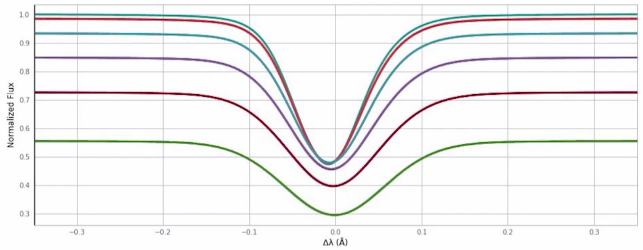
Goal: use interpolation to estimate data for radial angle locations which are not computed to increase accuracy of disk-integrated data with minimal computation

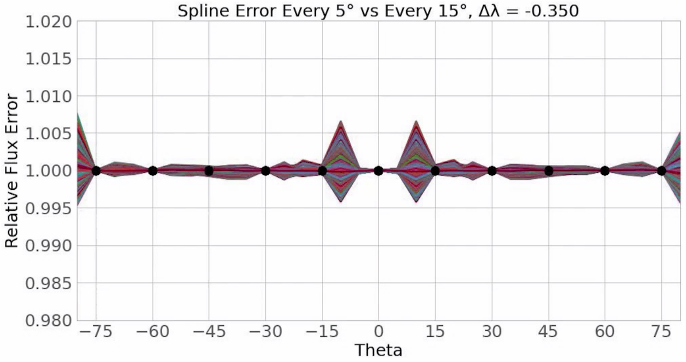


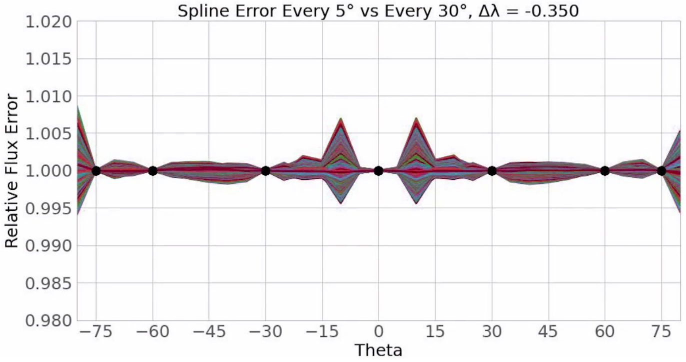
Interpolation

Method:

- Plot intensity at one wavelength (vertical black line in animation) vs angle from disk center, compute polynomial spline for plot, repeat for all wavelengths in profile (256 total)
- To test this method, a 100 minute long disk-integrated timeseries was computed for both the original data (every 15°) and the original+interpolated data. These were then compared to computing for every 5° in radial angle





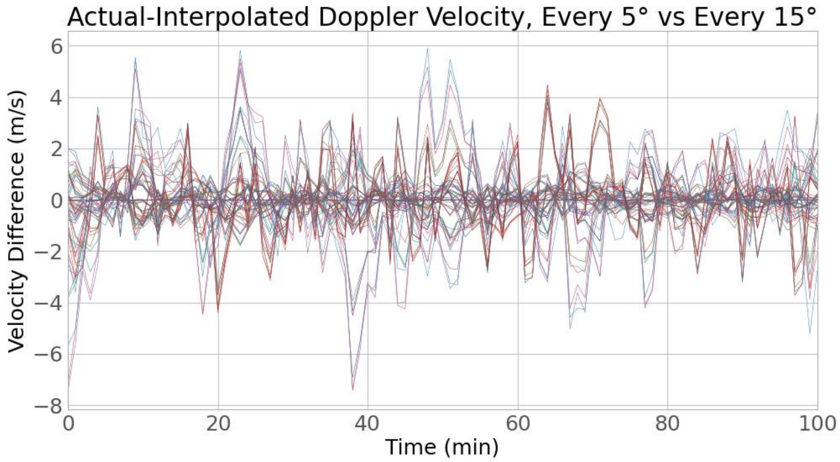


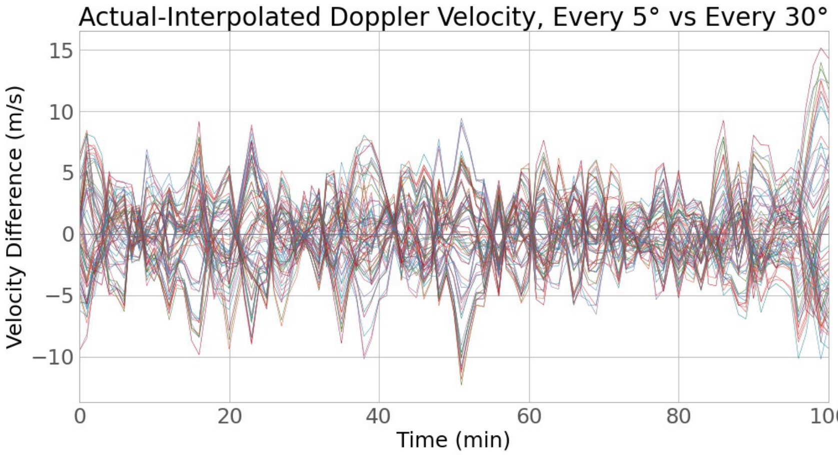
Interpolation

Maximum Error in computed doppler velocity:

- Every 15°: ~7m/s
- Every 30°: ~15m/s

Orbiting Earth-mass planet perturbs host star on scale of 0.1m/s - 1m/s, therefore error is too large





Key Conclusions

- The development of our ability to accurately model the stellar jitter and its effects is essential in expanding our ability to detect Earth-mass exoplanets orbiting Sun-like stars via the RV method

- Hydrodynamic and Magnetohydrodynamic simulations and synthetic data sets with higher spatial and temporal resolutions are required for a more realistic representation of observational data

- Further sampling of locations near the limb corresponding to intermediate polar angles, whether through computation or interpolation, is likely necessary for a more realistic representation of observational data

Acknowledgements:

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